526

Synopsis on the Biology of the Jack Mackerel (*Trachurus symmetricus*)

By John S. MacGregor

SPECIAL SCIENTIFIC REPORT—FISHERIES No. 526

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

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FAO Species Synopsis No. 86

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Washington, D.C.
April 1966

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ABSTRACT

This synopsis brings together all extant knowledge of the jack mackerel. This knowledge covers nomenclature, taxonomy, morphology, distribution, ecology and life history, population, exploitation, and protection and management.

INTRODUCTION

The Fisheries Biology Branch of F.A.O. has formed a "Synopsis Association" composed of fishery agencies willing to contribute to the preparation of synopses on fishes and other aquatic organisms of commercial value. As of this time several organizations, including the Bureau of Commercial Fisheries, have agreed to collaborate with F.A.O. in this undertaking. Some Bureau of Commercial Fisheries personnel have already prepared species synopses, issued by F.A.O. Fisheries Biology Branch, in connection with the world species meetings on sardine and tuna. Under the present agreement the Bureau has assigned the preparation of synopses on various economically important species to a number of its laboratories. These synopses will be published in the Special Scientific Report--Fisheries series, and will follow the format presented in "Preparation of Synopses on the Biology of Species of Living Aquatic Organisms" by H. Rosa Jr., Biology Branch, Fisheries Division, F.A.O.

The primary purpose of this series is to make existing information readily available to fishery scientists, according to a standard pattern, and by so doing also to draw attention to gaps in knowledge. It is hoped that synopses in this series will be useful to scientists initiating investigations of the species concerned or of related ones; as a means of exchange of knowledge among those already working on the species, and as the basis for comparative study of fishery resources.

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Trachurus symmetricus (Ayres), Proc. Cal. Acad. Nat. Sci. 1: 1855, 62.

1.12 Synonymy

Caranx symmetricus Ayres, Proc. Cal. Acad. Nat. Sci. 1, 1855: 62. (San Francisco).

Trachurus symmetricus (Ayres) Gill, Proc. Acad. Nat. Sci. Phila. 1862: 261. (Cape San Lucas).

Caranx picturatus (Bowdich); Jordan and Gilbert, Proc., U.S. Nat. Mus. 1882; 269. (Monterey, Santa Barbara, San Pedro, Cape San Lucas).

Trachurus picturatus (Bowdich), Jordan and Gilbert, Proc. U.S. Nat. Mus. 1882, 269. Proc. U.S. Nat. Mus. 1883: 191. (Monterey, Santa Barbara, San Pedro, Cape San Lucas).

Trachurus picturatus (Bowdich). Jordan and Everman, Bull. U.S. Nat. Mus., 47, 1896; 909. (San Francisco, Monterey, Santa Barbara, San Pedro, Cape San Lucas).

Decapterus polyaspis Walford and Myers, Copeia. 1944: 45. (Oregon, British Columbia).

Trachurus symmetricus (Ayres) Roedel and Fitch, Copeia. No. 1, 1952; 4. (Oregon, British Columbia; Oregon to San Juanico Bay, Baja Calif.).

1.2 Taxonomy

1.21 Affinities

Phylum	Chordata
Class	Teleostomi
Order	Perciformes
Family	Carangidae

TRACHURUS

Scomber Linnaeus, 1758, Systema naturae, Ed. X, vol. 1: 298, Scomber, trachurus Linnaeus after Scomber linealaterali aculeata of Artedi.

Trachurus Rafinesque, 1810: Caratteri di Alcuni Nuovi Generi e Nuove Specie di Animale e Piante della Sicilia, p. 41, Type: Scomber trachurus Linnaeus = Trachurus saurus Rafinesque.

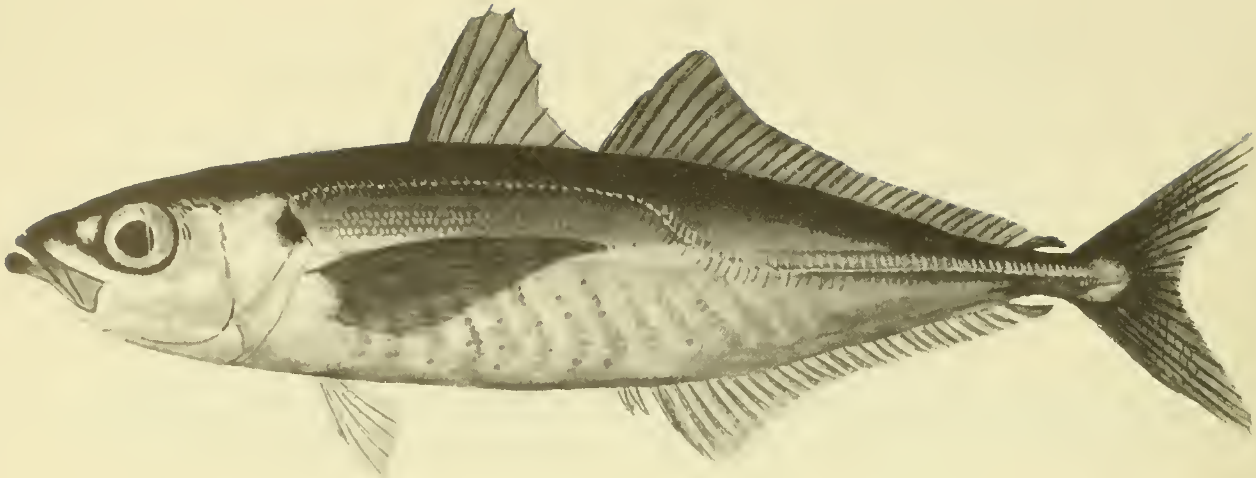

Figure 1.--Trachurus symmetricus (Ayres) (Drawing by George Mattson USFWS).

The genus Trachurus may be separated from the other genera of the subfamily Caranginae by the lateral line scutes which are present along the entire lateral line in Trachurus and either absent or confined to the posterior part of the body in the other genera.

Roedel and Fitch (1952) gave the following diagnosis of Trachurus symmetricus based on 1,100 specimens ranging in standard length from 93 to 557 mm. and collected from Oregon to central Baja California: "On the basis of these 1,100 fish, we conclude that in T. symmetricus, the accessory lateral line usually extends to the insertion of the second dorsal fin. It may end as far forward as the fourth dorsal spine or as far posterior as the fifth dorsal soft ray. All scales in the lateral line are enlarged. The lateral line is curved abruptly downward about under the insertion of the second dorsal and becomes straight under the eighth to eleventh dorsal ray. The length of the chord of the curved portion is usually, but not always, greater than the length of the straight portion. Scales number 52(41-59) in the curved portion and 46 (40-55) in the straight; total scales are 99(87-111). Other counts are: gill rakers 15 (13-18) + 41 (37-45) = 56 (51-61); gill teeth 7 (5-9) + 27 (25-30) = 34 (31-39); first dorsal fin, VIII; second dorsal I, 33(28-38); anal II-1, 29 (22-33). The last dorsal and the last anal rays become progressively more finletlike in structure as the fish grows and in large individuals appear to be detached finlets. However, a very fine membrane or its remnants can usually be detected in carefully handled individuals."

Most earlier authors tended to place the various geographic populations of Trachurus into two species, T. trachurus (L) and T. picturatus (Bowdich), with T. symmetricus in the latter. In 1920 Nichols described the Peruvian form as T. murphyi and included a key to the species of Trachurus. Hildebrand (1946) was unable to separate T. symmetricus and T. murphyi using Nichol's key, but could distinguish them on the basis of gill rakers on the lower limb of the first arch and depth of scutes. Roedel and Fitch (1952) also used height of scutes and, in addition, relative pectoral fin length to separate the two species.

Hildebrand found that seven specimens of murphyi 485 to 497 mm. standard length had 45-48 gill rakers on the lower arch and six specimens of symmetricus of undetermined length had 40-42. Roedel and Fitch gave 37 to 45 as the range for 1,100 symmetricus 93 to 557 mm. long. No data are given for their two specimens of murphyi.

Roedel and Fitch found that pectoral length was contained 3.2 times in standard length in two murphyi 275 and 323 mm. and 3.6 to 4.5 times in 200 symmetricus 250 to 350 mm. Although not stated by Hildebrand, his pectoral-in-length measurements appear to be based on total length. On the basis of standard length his measurements would be approximately 3.0 to 3.5 for an unstated number of small murphyi 60-117 mm. and 4.3 to 4.6 for seven large specimens 485-497 mm. The data on pectoral-in-head given by Walford and Meyers (1944) for five large specimens of symmetricus 380 to 510 mm. ranged from 4.2 to 4.9. Apparently as in other Carangids (Berry, 1959), the pectoral length increases at a relatively greater rate with growth than does body length.

Hildebrand used height of highest scale in the curved portion of lateral line into head and height of highest scale in the straight portion of lateral line into head to separate the two species. Roedel and Fitch expressed scale height as a percentage of head length. Data from both as percentage of head length are as follows:

	T. murphyi (Peru)		T. symmetricus (Calif.)	
	Curved	Straight	Curved	Straight
Roedel and Fitch (1952).........	18.3-19.8	18.3-20.0	9.5-14.1	12.2-16.9
Hildebrand (1946).................	15.9-20.0	15.9-21.3	10.5-11.9	12.7-14.9

The greater range of Hildebrand's Peru data and Roedel and Fitchs' California data reflect larger numbers of specimens. Otherwise it is apparent that the largest scales in both the curved and straight portions of the lateral line of murphyi are about equal size; they are about 60 percent larger than the largest scale in the curved portion of the lateral line of symmetricus and about 30 percent larger than the largest scale in the straight portion.

Roedel and Fitch, using all specimens of Trachurus in the collections of the California Academy of Science and Stanford University stated:

> "On the basis of published descriptions and comparisons with the specimens available to us, T. symmetricus appears to be readily distinguishable from all other species except the Atlantic T. picturatus (Bowdich). A direct comparison of material will be necessary before the relationship of these two can be determined."

The differences between only symmetricus and murphyi are discussed in their paper.

1.22 Taxonomic status

See above.

1.23 Subspecies

See above.

1.24 Standard common names, vernacular names.

The name sanctioned by the state of California for purposes of record keeping is jack mackerel. Other names are: horse mackerel, Spanish mackerel, jackfish, saurel, agii, jurel, macarella caballa.

1.3 Morphology

1.31 There seems to be very little individual variation among jack mackerel, and no geographic variation has been reported. Clothier (1950) found that of 816 jack mackerel from Monterey Bay and Southern California, 813 (99.6 percent) had 24 vertebrae, one had 23, and two had 25. The species appears to consist of a single population.

As the fish increase in length it appears that the relative lengths of the pectoral fins increase, and the last two rays in the dorsal and anal fins become more finletlike in appearance.

1.32 Cytomorphology

No data available.

1.33 Protein specificity

No data.

2 DISTRIBUTION

2.1 Total area

The population appears to have its maximum density in California coastal waters (46.3) between Point Conception, California, and central Baja California. The range limits of the population have not been determined fully as noted below. Extensive egg and larva surveys along the U.S. and Baja California coasts indicate that the greatest amount of jack mackerel spawning takes place between Point Conception and Baja California between 80 to 240 miles offshore (Fig. 2). The seaward extension of spawning has not been delimited by the present surveys. Abundance of eggs and larvae decreases to the south, and none are taken off southern Baja California. Spawning also occurs at least as far north as Washington State. In August 1955, eggs and larvae were taken on a special cruise (NORPAC) at stations off the Oregon and Washington coasts to 150° west longitude (or about 1/4 of the distance from U.S. to Japan) which was as far as the cruise extended (Ahlstrom, 1956).

According to Fitch (1956) adult jack mackerel have been taken more than 600 miles off the southern California coast and along the coast from British Columbia to Cape San Lucas, Baja California. Juveniles have been taken farther

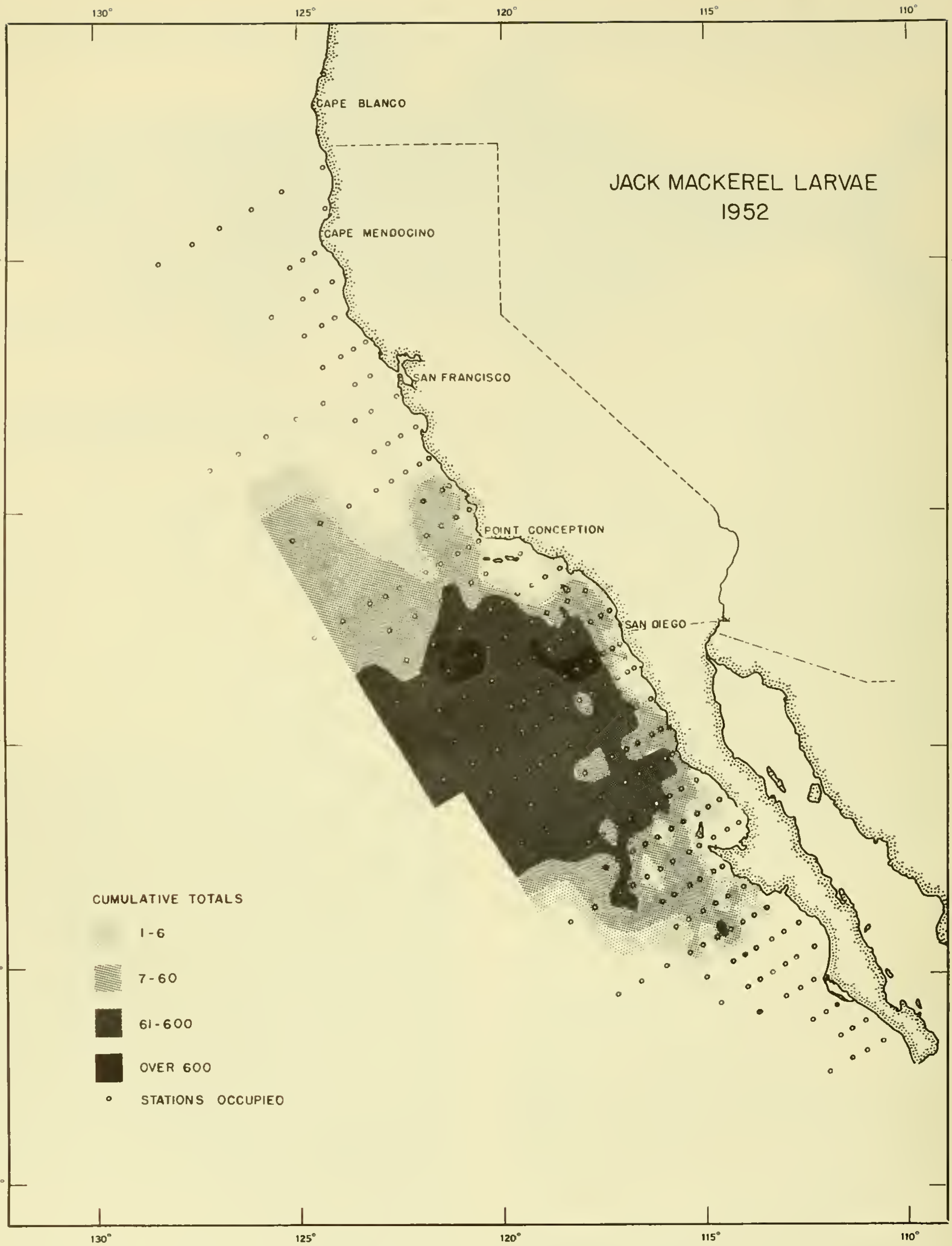

Figure 2.--Distribution of jack mackerel as indicated by larval distribution.

to the south, at the Revillagigedo Islands and reportedly at Acapulaco and in the Gulf of Tehauntepec, Mexico. The latter two records may be fish transported south in bait tanks of tuna boats.

The record of Clemens and Nowell (1963) of one specimen of T. symmetricus taken off Costa Rica at lat. 10° 01'N., long. 85° 55' W. by dip net and night light in July 1957 has been found to be in error.

2.2 Differential distribution

The distribution of adult jack mackerel appears to correspond closely to that of eggs and larvae. The adults are present off southern California throughout the year, and seasonal and annual variations in landings are caused by primarily economic factors acting upon the fishing industry.

2.3 Determinants of distribution changes

Jack mackerel eggs and larvae have been taken for the past 15 years at most California Cooperative Oceanic Fisheries Investigation (CalCOFI) stations off southern California and northern Baja California except for those closest to shore. The catch of adults also indicates that the population is more stable with respect to distribution and more offshore than the other three small pelagic species, the sardine, Sardinops caerulea (Girard), the Pacific mackerel, Pneumatophorus diego (Ayres), and the anchovy, Engraulis mordax Girard, taken by the purse seine fishery.

2.4 Hybridization

No evidence of hybridization.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Jack mackerel are heterosexual and without apparent sexual dimorphism.

3.12 Maturity

According to Fitch (1956) 50 percent of females are mature at 250 mm. fork length and age 2; 100 percent at 350 mm. and age 3.

3.13 Mating

No record of observation but probably promiscuous.

3.14 Fertilization

External.

3.15 Gonads

No data are available on the relation of number of eggs to age and body length and weight for the jack mackerel. Within most fish species the number of eggs produced at one time is approximately proportional to the weight and the cube of the length of the fish.

Fecundity data for a jack mackerel taken off central Baja California in July 1953 are as follows:

Standard length........................	215 mm.
Fork length............................	229 mm.
Total length	242 mm.
Weight	171 grams
Gonad weight (left 3.17) (right 2.97)...........	6.14 grams
Eggs (0.40-0.58 mm. diameter ...	52,600
Eggs per gram of fish..............	308

The pelagic eggs of marine fishes of most species have diameters within a few tenths of 1 millimeter. The number of eggs per gram of fish, developed as one spawning batch, tends generally to be high for small species of fish (i.e. about 600 eggs per gram of fish for Vinciguerria lucetia (Garman) weighing less than 1 gram and having ripe-egg diameters of about 0.7 mm.) and low for large species of fish (i.e. less than 50 eggs per gram of fish for some of the large tunas weighing over 100 kg. and having ripe-egg diameters of about 1 mm.).

The 308 eggs per gram of fish and ripe-egg diameter of about 1 mm. for the jack mackerel are typical for a fish of this size producing a pelagic egg. A scombrid, the Pacific mackerel--which inhabits much of the same range as the jack mackerel, is of similar size and has many comparable habits--spawns a pelagic egg about 1.1 mm. in diameter and produces 304 eggs per gram of fish (based on counts for six specimens).

3.16 Spawning

The percentage frequency distribution of diameters of eggs containing yolk found within the ovaries of the 215 mm. jack mackerel (see preceding section) are presented in Figure 3. Numerous eggs less than 0.20 mm. diameter and not containing yolk are not shown. The eggs that form a distinct mode from 0.40 to 0.58 mm. diameter are considered to be the group destined to be spawned. A bimodal distribution of yolked eggs may indicate two spawnings. The ratio of eggs 0.20 to 0.38 mm. to eggs 0.40 to 0.58 mm. diameter

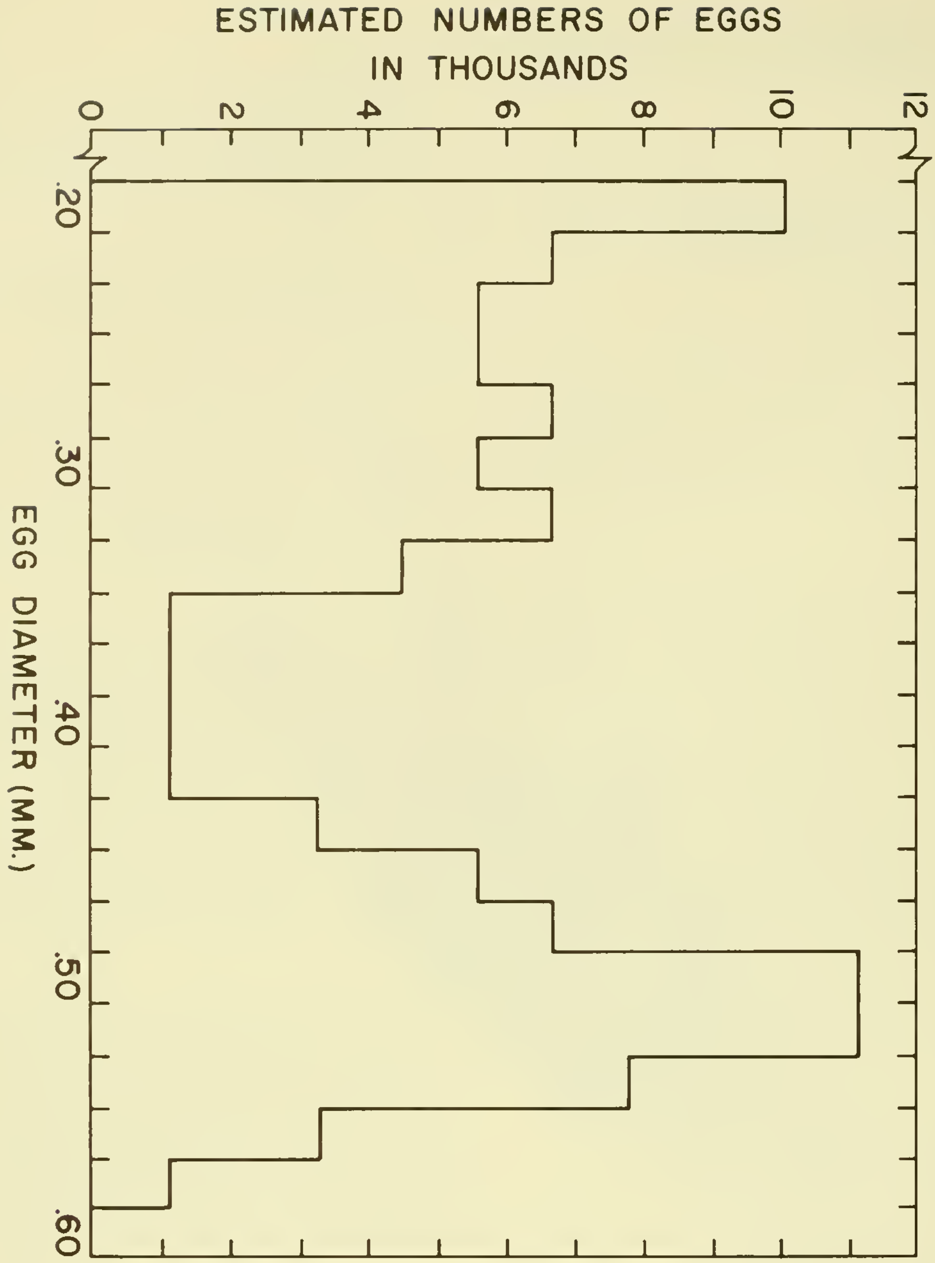

Figure 3.--Frequency distribution of diameters of eggs from a jack mackerel ovary.

is approximately 1 to 1. Alternatively the eggs 0.20 to 0.38 mm. may be only an extension of the large mode of nonyolked eggs that is resorbed following spawning of the more advanced yolked eggs. The presence of a bimodal size distribution of yolked eggs in the developing ovaries of fish species that spawn pelagically seems to be a typical condition, but whether this bimodality means the fish will necessarily spawn more than once is an unsettled question.

Plankton tows taken at monthly intervals at the CalCOFI stations off the coasts of California and Baja California reveal the following seasonal occurrence for the 105,776 jack mackerel larvae taken in the 7-year period 1951-57:

Month	Total number of larvae	Percentage of total	Month	Total number of larvae	Percentage of total
January	36	0.03	July	10,726	10.1
February	2,457	2.3	August..........	986	.9
March	13,014	12.3	September.....	320	.3
April.............	19,441	18.4	October	183	.2
May	26,800	25.3	November	14	.01
June..............	31,799	30.1	December	0	.00

The average age of the above larvae is 6.6 days from spawning, and therefore the larval occurrences should adequately indicate the spawning season.

Farris (1961) determined the daily distribution of spawning by plotting the relative abundance of precleavage eggs against time of collection. He found that about one-third of these newly spawned eggs were taken in the hour between 2330 and 0030, and almost two-thirds in the 4 hours between 2030 and 0030; spawning activity seemingly reaches a peak shortly before midnight.

On monthly survey cruises, 1950 through 1952, Ahlstrom and Ball (1954) took jack mackerel larvae at water temperatures (20-meter depth) of 10° to 19.5° C., but over 70 percent of the larger concentrations of larvae (50 or more larvae per standardized haul) occurred within a 2° range, 14° to 16° C. They also found that 80.1 percent of the larvae occurred offshore between Point Conception, California, (about lat. 35° N.) and San Quentin Bay, Baja California, (about lat. 30° N.); 10.7 percent of the larvae were taken north of this area and 9.2 percent south. The spawning area did not appear to extend south of the area surveyed, but there was probably some spawning to the north outside the survey area.

Spawning as indicated by percentage occurrence of larvae (adjusted to number of stations) relative to distance offshore was as follows:

Coast	to	80 miles.......	9.9
81	to	160 do...........	32.7
161	to	240 do...........	39.9
241	to	320 do...........	15.0
321	to	400 do...........	2.5

Spawning probably also extended farther seaward than the survey area.

3.17 Spawn

On the basis of 538 eggs taken during April and May 1950 from various parts of the spawning range, Ahlstrom and Ball (1954) described the jack mackerel egg as pelagic, nonadhesive, spherical, 0.98 mm. (range 0.90-1.08) in diameter, with a yolk 0.80 mm. (0.68-0.88) in diameter, a single oil globule 0.26 mm. (0.18-0.35) in diameter, and a perivitelline space 0.09 mm. wide (fig. 4). The eggshell is clear, tough and unsculptured. The irregularly segmented yolk mass appears yellow to amber in preserved material.

Ahlstrom (1959 table 7) showed that 97 percent of the jack mackerel eggs and 88 percent of the larvae are found in the upper 50 meters of water. Few eggs or larvae are found below 100 meters and none below 140 meters.

3.2 Pre-adult phase

3.21 Embryonic phase

Embryonic development of the jack mackerel is typical of most fish with pelagic eggs. One identification feature present throughout embryonic development is the segmentation of yolk material which is usual in the eggs of isospondylid fishes, but unusual in those of percomorph fishes. Ahlstrom and Ball (1954) gave a detailed description of the embryonic development of the jack mackerel (Fig. 4).

According to data presented by Farris (1961), incubation time from spawning to the last stage before hatching follows the formula $\log \underline{Y} = 3.257 - 0.088X$ in which $\underline{Y}$ = hours and $\underline{X}$ = temperature in degrees Centigrade. Thus incubation time would be 2 days at 17.9° C., 3 days at 15.9° C. and 4 days at 14.5° C.

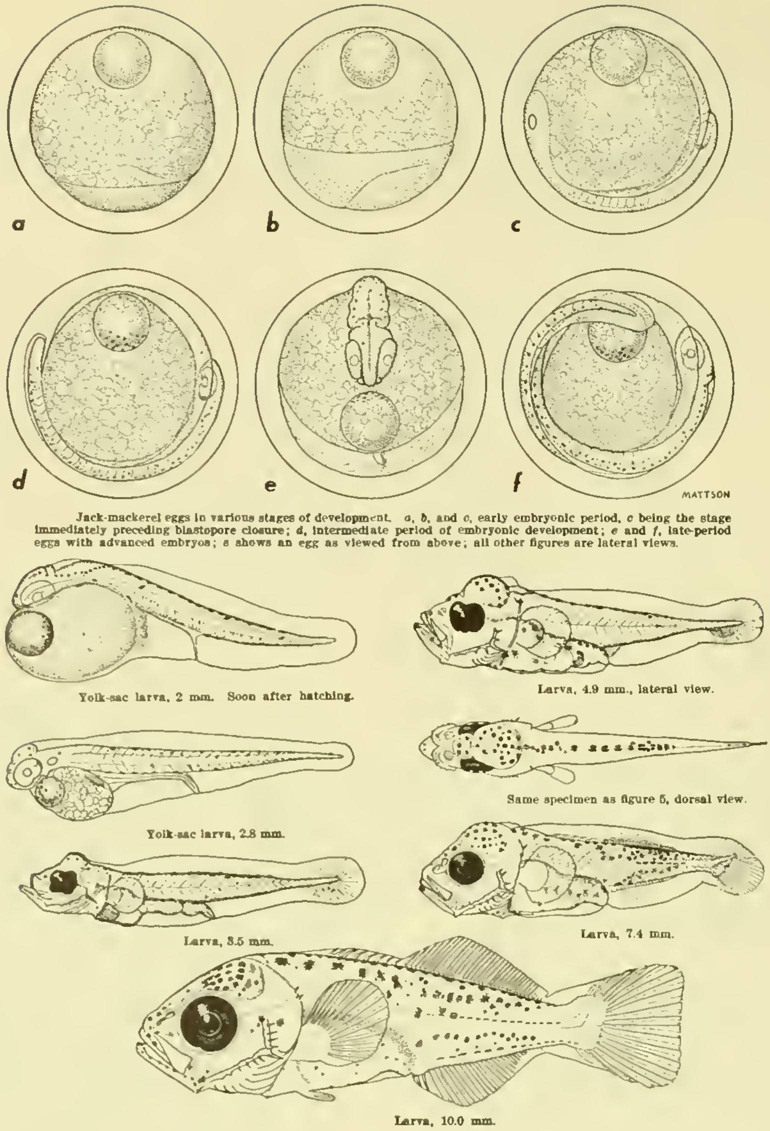

Figure 4.--Eggs and larvae of jack mackerel (figures 1 through 8 of Ahlstrom and Ball, 1954).

3.22 Larval phase

Ahlstrom and Ball (1954) gave a detailed description of the development of jack mackerel larvae (fig. 4). Jack mackerel hatch in a relatively undeveloped condition--before the mouth is formed, before the eyes are pigmented, and before any fin formation. In preserved material the larvae average 2.07 mm. (range 1.91 to 2.38) at hatching. During the yolk-sac stage the eyes may begin to develop pigment in larvae as small as 2.2 mm. The jaws develop rapidly and begin to ossify--the upper jaw in larvae between 3 and 3.5 mm. long, and the lower, in larvae between 3.2 and 3.8 mm. The following table gives the approximate length at which the first spine or ray appears and the approximate length at which the full complement of spines or rays is attained for each fin.

Fin	Full complement	Fish length when first ray or spine appears	Fish length when full complement is attained
Caudal:		Mm.	Mm.
Principal rays	17	5-6	8
Secondary rays	18-20	8	16
Pectoral rays	22-24	6	14
Anal spines	3	7	9
Anal rays	28-31	7	14
First dorsal spines	8	8	12
Second dorsal spine	1	8	
Second dorsal rays	30-35	7	14
Ventral spine	1	11	
Ventral rays	5	9	11

The very small jack mackerel feed primarily on minute crustaceans; the food particle size ingested by mackerel of about 3 mm. length ranges from 0.04 to 0.18 mm. diameter and by mackerel of about 9.5 mm. length from 0.10 to 0.56 mm. (Anonymous, 1953).

The size of larvae (based on preserved material which may shrink as much as 20 percent) at the end of the yolk-sac stage is as follows (Ahlstrom and Ball, 1954):

Size group	Number examined	Number with yolk	Percentage with yolk
Mm.			
2.00-2.49	8	8	100
2.50-2.99	18	11	61
3.00-3.49	16	4	25
3.50-3.99	15	1	7
4.00-4.59	15	0	0

Farris (1959) gave the following data on larval growth for live larvae that were not given any nourishment other than that in the yolk; the yolk sacs were absorbed by the sixth day.

Numbers of larvae	Days past hatching	Average length (millimeters)
4	0	2.0
17	1	2.6
12	2	2.9
14	3	3.4
10	4	3.5
11	5	3.5
9	6	3.7
7	7	3.8
3	8	3.7
3	9	3.7
3	10	3.5
2	11	3.4

On the basis of the above and other data on larvae Farris (1959, 1960, 1961) obtained growth and survival curves for larval jack mackerel. His survival curves are based on the questionable growth curves obtained from measurements of starving larvae, and therefore any advantages of his curve of survival with age over the curve of survival with length are lost. The length frequency distributions of larvae taken in 1952 through 1957 (table I) may be used as length-survival curves if the numbers of larvae in the 0.50 mm. intervals (2.00 to 5.00 mm.) are doubled. If the 6-year totals so adjusted are plotted on semilog paper it is apparent that the length intervals at 3.50 through 7.75 have an excellent straight-line relationship to numbers of larvae. That is, if $\underline{Y}$ = numbers of larvae, and $\underline{X}$ = length in mm, log $\underline{Y}$ = a-0.36428$\underline{X}$ or $\underline{Y}$ = antilog $\underline{a}$ (0.43224$\underline{X}$) or survival is 43 percent for each millimeter of length increase from 3.50 to 7.75 mm. The value of "$\underline{a}$" may be adjusted so that a predetermined number of larvae at hatching (2.00 mm.) may be used as a starting point. In Figure 5 the observed numbers of larvae were multiplied by 9.5427 to obtain a computed value at 2.00 mm. of 1 million larvae. The relation between length and numbers of larvae is log $\underline{Y}$ 5.74889 - 0.36428$\underline{X}$. The fact that larvae smaller than 3.5 mm. fall progressively farther below the extrapolated line is explained by the incomplete retention of very small larvae by the plankton nets. This selection bias is discussed in detail by Farris (1961). The data indicate that, unless the mortality of these very small larvae is different from that of the larger ones, the nets retain about 15 percent of 2.0-mm. larvae, 47 percent of 2.5-mm. larvae and 86 percent of 3.0-mm. larvae.

Table 1.--Jack mackerel larvae of different lengths caught in standard hauls 1952-57

Standard length		Year						
Range	Midpoint	1952	1953	1954	1955	1956	1957	Total
Mm.	Mm.	No.	No.	No.	No.	No.	No.	No.
1.75- 2.25	2.00	1,714	1,005	1,603	791	333	2,173	7,619
2.25- 2.75	2.50	3,512	1,646	4,126	1,797	805	4,283	16,169
2.75- 3.25	3.00	4,896	1,614	3,690	3,026	1,662	4,570	19,458
3.25- 3.75	3.50	4,143	842	2,040	2,803	1,486	3,610	14,924
3.75- 4.25	4.00	3,018	679	1,184	1,509	1,225	1,881	9,426
4.25- 4.75	4.50	1,949	567	672	869	962	1,291	6,310
4.75- 5.25	5.00	1,355	445	685	750	560	677	4,472
5.25- 6.25	5.75	1,184	506	524	964	601	808	4,587
6.25- 7.25	6.75	343	335	271	436	211	375	1,971
7.25- 8.25	7.75	141	124	91	160	97	207	820
8.25- 9.25	8.75	53	51	26	52	19	59	260
9.25-10.25	9.75	37	37	12	46	18	28	178
10.25-11.25	10.75	15	7	6	15	9	26	78
11.25-12.25	11.75	9	18	0	8	15	6	56
12.25-13.25	12.75	3	11	2	12	0	0	28
13.25-14.25	13.75	7	6	0	0	0	3	16

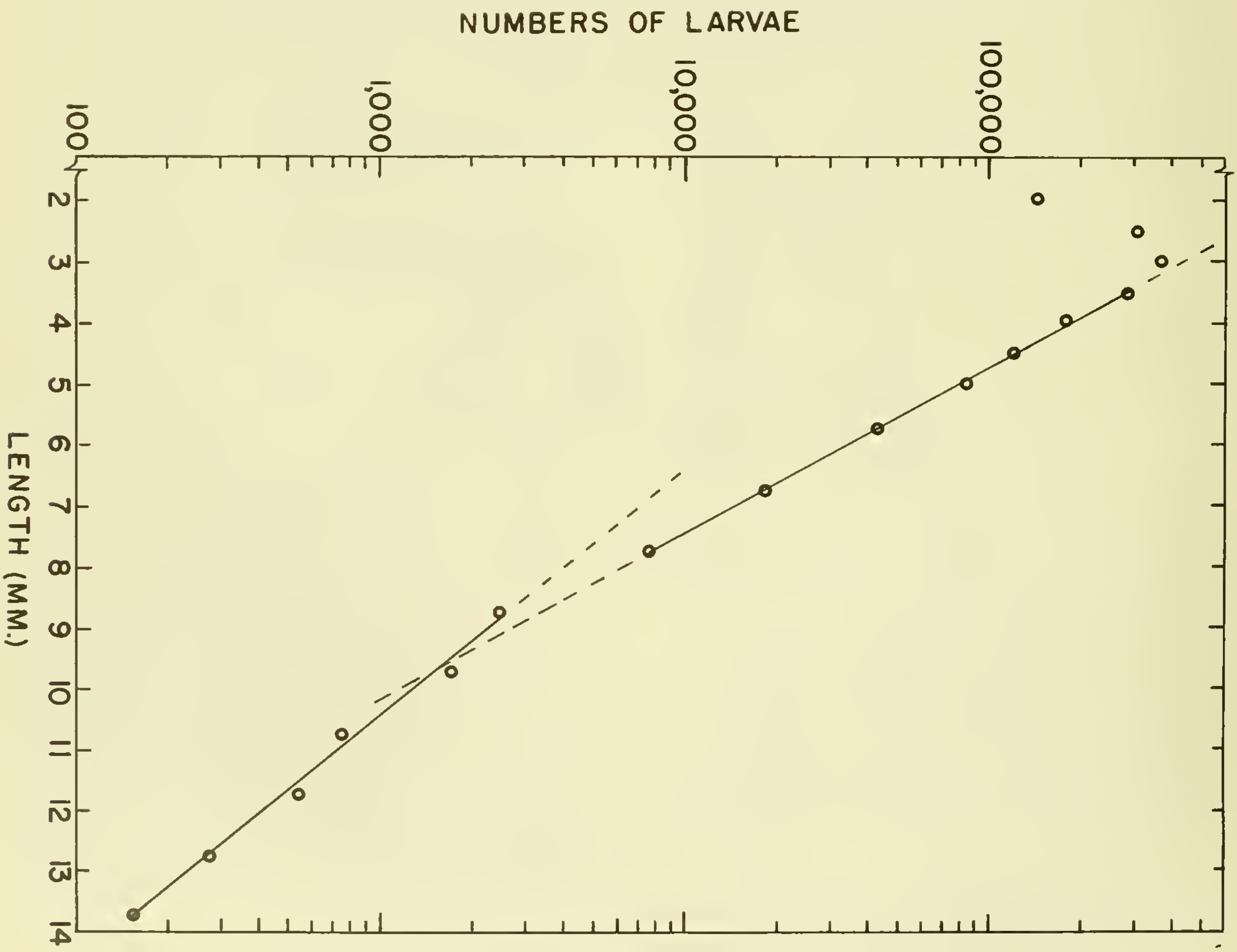

Figure 5.--Survival (length frequency) curve for larval jack mackerel.

The numbers of larvae larger than 7.75 mm. taken by plankton nets are undoubtedly affected by "net dodging." Most other larval fish taken with jack mackerel in plankton nets show an increase in the ratio of night-caught to day-caught larvae with increasing size of larvae. Farris found that the ratio of night-caught to day-caught larval jack mackerel remained approximately 1:1 for larvae 2 to 12 mm. He concluded that jack mackerel do not evade the net. A second interpretation is that they avoid the net equally well both by day and night.

The principal rays of the dorsal fin first appear at 5 to 6 mm. and a full complement is attained by 8 mm. The remaining fins begin to form at 6 to 8 mm. The resulting increased motility could decrease the capture of larvae by the net from a probable 100 percent (over the length range 3.50 to 7.75 mm.) of the larvae available to the net to considerably less.

Survival also appears to increase at this point. If the initial survival rate continued to 18.5 mm., only 1 larva of the original 1 million would survive and the adult stock could not replace itself. The first reduction in mortality appears to take place at about 8 mm. when the larvae become motile.

The apparent relation between numbers of larvae and length for the range 8.75 to 13.75 mm. may be described by log $Y = 5.57267 - 0.24594\underline{X}$, at this size range survival is 57 percent for each millimeter of length increase. This rate of survival would reduce the larval population to 1 fish at 22.5 mm. More probably, the larval mortality is decreasing with increasing size and motility of the fish above 8 mm.; the increasing motility of the fish also increases its ability to avoid the net, thus causing progressively greater undersampling of fish over 8 mm. There is no indication of a "critical period" in survival, and the only "abrupt" change in the survival curve occurs at the time of fin formation.

3.23 Adolescent phase

Little is known about the juvenile jack mackerel. Food studies show that copepods, euphausiids and pteropods constitute most of the food in stomachs, and that copepods are a more important food among juveniles than among adults (Anonymous, 1953).

3.3 Adult phase

3.31 Longevity

Most of the fish taken in the commercial catch are less than 6 years old; the majority are 2, 3, and 4 years old. On rare occasions very large jack mackerel from 10 to over 25 years old appear in the commercial catch (Anonymous, 1953) and some fish taken in the sport fishery have been reliably aged at over 30 years (Fitch, 1956).

3.32 Hardiness

No data.

3.33 Competitors

The Pacific mackerel, which is often caught with the jack mackerel and which has many similar habits, is probably the principal competitor.

3.34 Predators

Predation other than by man has not been studied.

3.35 Parasites, diseases, injuries, and abnormalities

No data.

3.4 Nutrition and growth

3.41 Feeding

Feeding takes place at any time of day. One method of catching mackerel at night makes use of chumming under lights, but whether or not they feed in the dark is unknown. Food is taken by selection and pursuit of individual food items.

3.42 Food

One study of food habits revealed that 90 percent by numbers of identifiable items in jack mackerel stomachs consisted of euphausiids, large copepods, and pteropods. Samples from cannery landings showed that at times jack mackerel feed almost exclusively on juvenile squid and anchovies. Large jack mackerel taken in offshore waters at night contained lantern fish. Both the mackerel and lantern fish were probably attracted to a light suspended over the stern of the vessel. Large jack mackerel taken by the sport fishery are usually caught with large adult anchovies as bait (Fitch, 1956).

3.42 Growth rate

Fish 2 years old are about 250 mm. long and 3 years, 350 mm. (Fitch, 1956). No other data have been published on growth of juvenile or adult jack mackerel. The following data on preserved specimens are available for condition factor $\underline{K} = \frac{\text{Weight} \times 10^7}{\text{Standard length}^3}$).

Date	Numbers of fish	Standard length range (mm.)	Condition factor	
			Mean	Range
II-20-59	2	147-193	146	135-147
III-25-52	5	211-218	128	120-135
VI- 9-60	10	233-260	163	140-177
VII-19-53	1	215	172	172
VIII-11-56	7	146-186	139	121-164
VIII-28-52	14	170-202	130	122-136

3.44 Metabolism

No data.

3.5 Behavior

3.51 Migrations and local movements

Practically nothing is known about the migrations and movements of the population. Very large specimens, to over 76 cm. and 2 1/4 kg. are taken in the inshore waters of southern California a month or two each summer by sport fishermen. These fish remain in the area a relatively short time and numbers caught fluctuate greatly from season to season as is shown in the following table (Fitch, 1956).

Sports catch of jack mackerel

Year	Number	Best month
1947	4,500	September
1948	2,400	August
1949	2,900	Do.
1950	600	July
1951	200	Do.
1952	4,400	May
1953	196,300	August
1954	19,400	June
1955	39,600	May

3.52 Schooling

The jack mackerel is a schooling fish, and tends to school by size. It is taken in company with Pacific mackerel and sardines as well as in pure schools.

3.53 Responses to stimuli

The jack mackerel is attracted to lights at night, or at least by the food attracted to the lights.

4 POPULATION

4.1 Structure

4.11 Sex ratio

The sex ratio of the catch appears to be about 1:1.

4.12 Age composition

Most of the jack mackerel in the commercial catch have been less than 6 years old and the majority either 2, 3, or 4 years.

Sexual maturity is attained by 50 percent of the female mackerel at age 2 and 100 percent at age 3.

Very large mackerel, more generally taken by the sport fishery, are as old as 30 years or more.

4.13 Size composition

Most of the commercial catch consists of fish 20 to 38 cm. total length.

Sexual maturity is attained by 50 percent of the female mackerel at 25 cm. fork length (2 years old) and 100 percent at 35 cm. fork length (3 years old).

Jack mackerel taken erratically in the salt-water sport fishery range from 45 to over 75 cm. total length and to 2.3 kg. These large jack mackerel appear in inshore waters only a month or two during the summer (Fitch, 1956).

From preserved material fork length was found to equal 1.08 times standard length, and total length was 1.19 times standard length.

4.2 Abundance and density (of population)

No data available.

4.3 Natality and recruitment

No data available.

4.4 Mortality and morbidity

No data available.

4.5 Dynamics of population (as a whole)

No data available.

4.6 The population in the community and the ecosystem

No data available.

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gears

Jack mackerel have been taken incidentally to the sardine and Pacific mackerel fisheries for many years by the same gear used in these fisheries. When the mackerel fishery developed suddenly in 1947 because of the decline in sardines and to a lesser extent Pacific mackerel, the purse seines of the sardine and Pacific mackerel fishery continued to be used for the jack mackerel. Scofield (1951) described in detail purse seines and other round haul nets that have been used in California fisheries. Before the development of the fishery for jack mackerel they were also taken in small quantities in the ring nets and lampara nets used by the sardine fishery before the purse seine came into general use.

Jack mackerel are also taken by the fishermen who fish for Pacific mackerel for the fresh fish market and to a lesser extent for canneries. Various methods have been and are used in this fishery, including hand lines, long lines, jigs, gill nets, and scoop nets, often in conjunction with chumming and/or lights (Croker, 1933, 1938).

Improvements in ship gear and fishing methods of the purse seine fleet include installation of ship-to-ship radios, echo-sounding gear, and power blocks, and the use of motor skiffs, synthetic netting materials, and airplane scouting.

5.12 Boats

The jack mackerel is taken primarily as a substitute or alternate cannery fish by the sardine fishing fleet. The sardine fleet consists of large purse seiners (over 60 feet or 18.3 meters in length) and assorted smaller purse seiners and lampara boats that are used in other fisheries when sardines are not available. Since the big increase in jack mackerel landings in 1947, this fleet attained its largest size during the 1949-50 season when it consisted of 372 vessels (including 135 smaller boats). In the 1960-61 season the California sardine fleet consisted of only 28 vessels (11 large purse seiners, 2 small purse seiners, and 15 lampara boats).

5.2 Fishing areas

Most jack mackerel are landed in the Los Angeles area (Roedel, 1953). Because this fishery is so closely allied to the sardine fishery, the area of the jack mackerel fishery closely coincides with that of the sardine (Fig. 6). The purse seiners are primarily seeking sardines; if sardines are scarce and there is a market for jack mackerel, these fish are taken instead whenever encountered. Actually the jack mackerel is distributed farther offshore than the sardine. In the 1952-53 sardine season the sardine catch was only about 3,000 tons, compared to over 120,000 tons the previous year. In the same season the jack mackerel catch was a record 73,000 tons, but 67 percent of this catch was made in the Tanner Bank-Cortez Bank area about 80 nautical miles offshore (Clothier and Greenhood, 1956). When sardines are more abundant the purse seiners do not range so far offshore.

Jack mackerel are also taken in unknown but relatively small amounts by Mexican purse seiners off northern Baja California.

In southern California and to a lesser extent in central California, jack mackerel are taken in small quantities primarily for the fresh fish market.

5.3 Fishing seasons

Clothier and Greenhood (1956) stated: "Jack mackerel are present in the waters off California throughout the entire year, but since the fishery is carried on simultaneously with the sardine and Pacific mackerel fishery, and these species are taken chiefly during the fall and winter months, the jack mackerel landings decline to a minimum in the spring and early summer."

5.4 Fishing operations and results

5.41 Effort and intensity

Effort and intensity are so influenced by the relationship to the sardine and Pacific mackerel fisheries as to be meaningless.

5.42 Selectivity

Selection factors primarily involved are the fishermen's ability to identify the species, size of school, and size of fish before setting their nets.

5.43 Catches

Table II gives the catch of Pacific mackerel, jack mackerel, and all mackerel for the years 1916-63.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory measures

6.11 Limitation or reduction of total catch

There are no legislative limitations on catch specifically pertaining to the jack mackerel. Canneries often place limits on the tonnage of jack mackerel that they will accept,

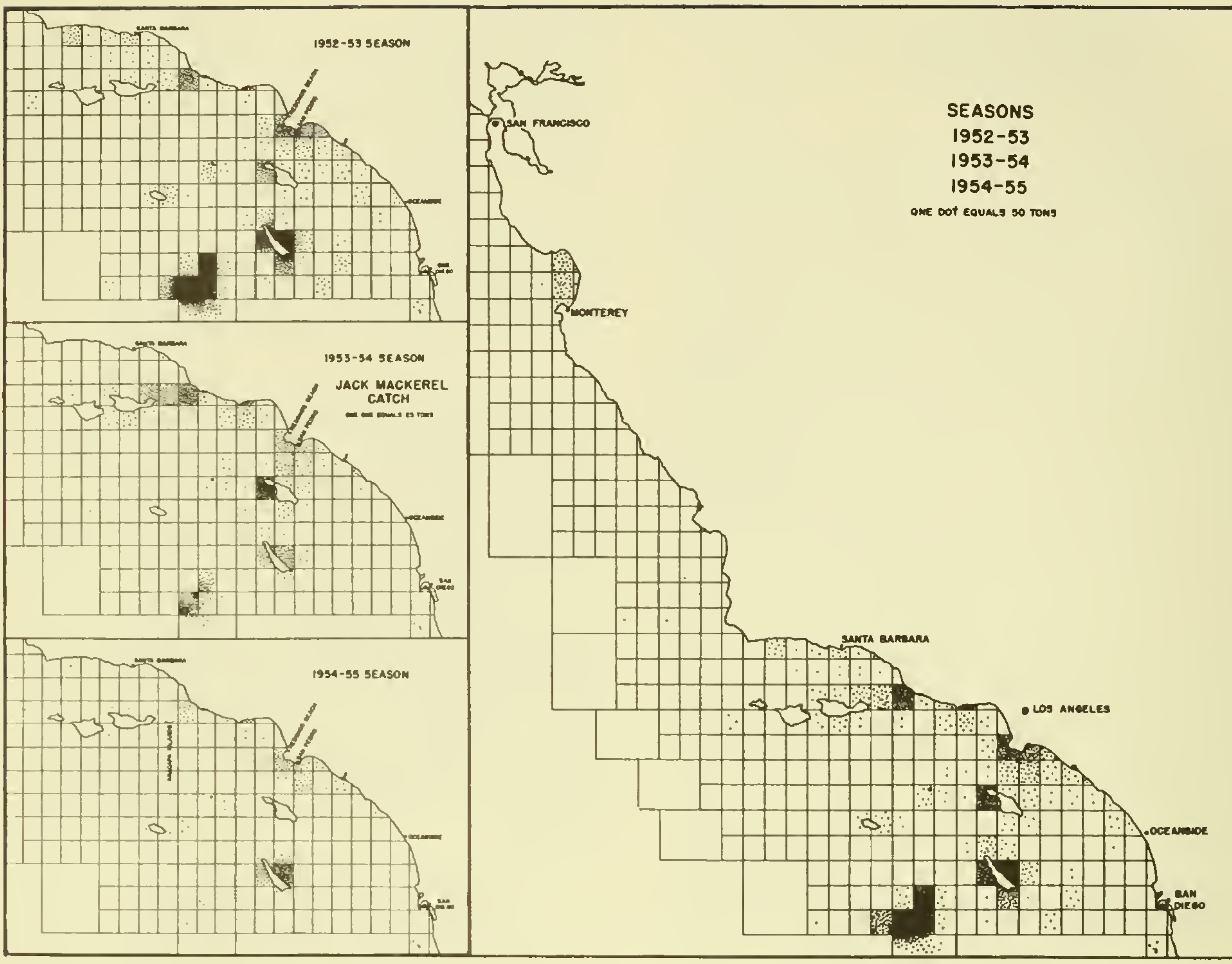

Figure 6.--Commercial fishing areas for jack mackerel in California (figures 3 and 4 of Clothier and Greenhood, 1956).

based on facilities available for handling the fish and on economic considerations.

6.12 Protection of portions of population

California has regulations pertaining to fishing gear and craft and also restrictions on commercial fishing in several relatively small areas. These regulations were not passed specifically to control the jack mackerel fishery and probably have little or no effect on it. There are no closed seasons or other restrictions on the jack mackerel fishery. California law prohibits the use of fish for reduction except that the fish offal may be reduced. The law also provides that the Fish and Game Commission may grant permits for the reduction of whole fish, but none have been granted for any species except sardines, and even reduction of sardines has not been allowed since 1948.

6.2 Control or alterations of physical features of the environment

None.

6.3 Control or alteration of chemical features of the environment

None.

6.4 Control or alteration of the biological features of the environment

None except those that may arise incidentally from fishing for jack mackerel, its predators, or competitors.

6.5 Artificial stocking

None.

7 POND FISH CULTURE

Does not apply.

Table 2.--California mackerel landings[1]

Year	Pacific mackerel Tons	Jack mackerel		Total Tons
		Tons	Percent of total landings	
1926..........	1,805	118	6.1	1,923
1927..........	2,364	231	8.9	2,596
1928..........	17,626	269	1.5	17,895
1929..........	28,987	349	1.2	29,336
1930..........	8,266	184	2.2	8,450
1931..........	7,127	282	3.8	7,409
1932..........	6,237	268	4.1	6,505
1933..........	34,907	505	1.4	35,312
1934..........	56,924	791	1.4	57,715
1935..........	73,214	4,992	6.4	78,206
1936..........	50,271	2,300	4.4	52,571
1937..........	30,468	3,271	9.7	33,739
1938..........	39,924	2,067	4.9	41,991
1939..........	40,455	1,880	4.4	42,335
1940..........	60,252	716	1.2	60,969
1941..........	39,084	1,034	2.6	40,118
1942..........	26,277	2,674	9.2	28,951
1943..........	37,607	6,349	14.4	43,957
1944..........	41,828	6,389	13.3	48,217
1945..........	26,858	4,516	14.4	31,375
1946..........	26,938	7,547	21.9	34,484
1947..........	23,239	64,534	73.5	87,763
1948..........	19,693	36,449	64.9	56,142
1949..........	24,881	25,625	50.7	50,506
1950..........	16,325	66,628	80.3	82,953
1951..........	16,759	44,919	72.8	61,678
1952..........	10,302	73,261	87.7	83,563
1953..........	3,751	27,875	88.1	31,626
1954..........	12,696	8,667	40.6	21,363
1955..........	11,656	17,877	60.5	29,533
1956..........	25,007	37,881	60.2	62,888
1957..........	31,022	41,006	56.9	72,028
1958..........	13,824	11,033	44.4	24,857
1959..........	18,801	18,754	49.9	37,555
1960..........	18,404	37,473	67.1	55,877
1961..........	22,055	48,803	68.9	70,858
1962..........	22,490	46,707	67.5	69,197
1963..........	18,259	48,319	72.6	66,578

[1] Landings of the two species of mackerel were not recorded separately in 1916-25. Combined landings (tons) were: 1916, 557; 1917, 1673; 1918, 2003; 1919, 1327; 1920, 1499; 1921, 1457; 1922, 1233; 1923, 1777; 1924, 1614; 1925, 1753.

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